A Stormwater Exfiltration System for an Urban Residential Development

Une solution d'exfiltration des eaux pluviales dans les projets de développement urbain résidentiel

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RÉSUMÉ

Un système d'exfiltration des eaux pluviales a été conçu pour gérer les eaux pluviales pendant quatre saisons dans un site résidentiel de Toronto, au Canada. En installant deux tuyaux de 200 mm perforés avec un embout capuchonné sous un égout pluvial (Fig. 1), le ruissellement de 15 mm de pluie en 2 heures remplirait les deux tuyaux de stockage perforés (à extrémité fermée), exfiltrerait vers l'espace vide de la fosse d'égout, puis exfiltrerait dans le sol environnant en permanence (en incluant la fonte de la neige et les précipitations d'hiver). Deux kilomètres et demi de ce système d'exfiltration ont été construits dans la ville de Toronto et il s'avère qu'ils peuvent gérer des précipitations prolongées jusqu'à 28 mm sans débordement de l'égout pluvial. Cet article présente les critères de conception et de planification, l'évaluation des coûts, la construction, la maintenance et l'évaluation de la performance grâce à un suivi. Ce système peut être appliqué aux nouveaux projets de développement résidentiel ainsi que pour la rénovation du système d'évacuation existant des eaux pluviales en zone urbaine.

ABSTRACT

A stormwater exfiltration system was designed to manage stormwater over four seasons at a residential site in Toronto, Canada. By installing two 200 mm perforated pipes with end capped below a storm sewer (Fig. 1), surface runoff of a design 15 mm of rainfall over 2 hours would fill up the two storage perforated pipe (with end capped), exfiltrate to the void space of the sewer trench, and subsequently exfiltrate to the surround soil at all times (i.e. including snowmelt and winter rainfall). Two and a half kilometer of this exfiltration system was constructed in the City of Toronto and found to be able to control long duration rainfall up to 28 mm without overflowing to the storm sewer above. This paper presents the planning and design criteria, costs, construction and maintenance, and performance evaluation by monitoring. This system can be applied to new residential development as well as stormwater retrofit in existing urbanized area.

KEYWORDS

Exfiltration, residential development, sewer trench, stormwater quality, water balance

1 INTRODUCTION

Traditionally stormwater management in Ontario and Canada focuses on impacts (e.g., flooding, erosion, water quality degradation) associated with summer and fall storms (which constitute about 30% of annual runoff in Ontario) and does not recognize Ontario's four unique seasons have on the planning, design, and operation of stormwater management practices. As a result, current stormwater management practices including low impact development practices (LID) are not seasonally managed to account for the unique and variable climatic characteristics of each of Ontario's four distinct seasons, resulting in poor state in many Ontario's water bodies (TRCA 2007; TRCA 2009). A unique LID, termed Etobicoke Exfiltration System (EES), was developed and implemented in a residential neighborhood of the City of Toronto. It consists of two 200 mm PVC perforated pipes with end capped below a storm sewer (Fig. 1). Surface runoff, from a upstream storm sewer, enters the two storage perforated pipe (with end capped), exfiltrates to the void space of the sewer trench, and subsequently exfiltrates to the surround soil at all times (i.e. including snowmelt and winter rainfall since it is below frost line). Two and a half kilometer of this exfiltration system was installed at a residential road reconstruction project in the City of Toronto and found to be able to control long duration rainfall up to 28 mm without overflowing to the storm sewer above. This paper presents the planning and design criteria, construction and maintenance, cost, and performance evaluation by monitoring (Li and Tran 2015). This system can also be applied to new residential development.

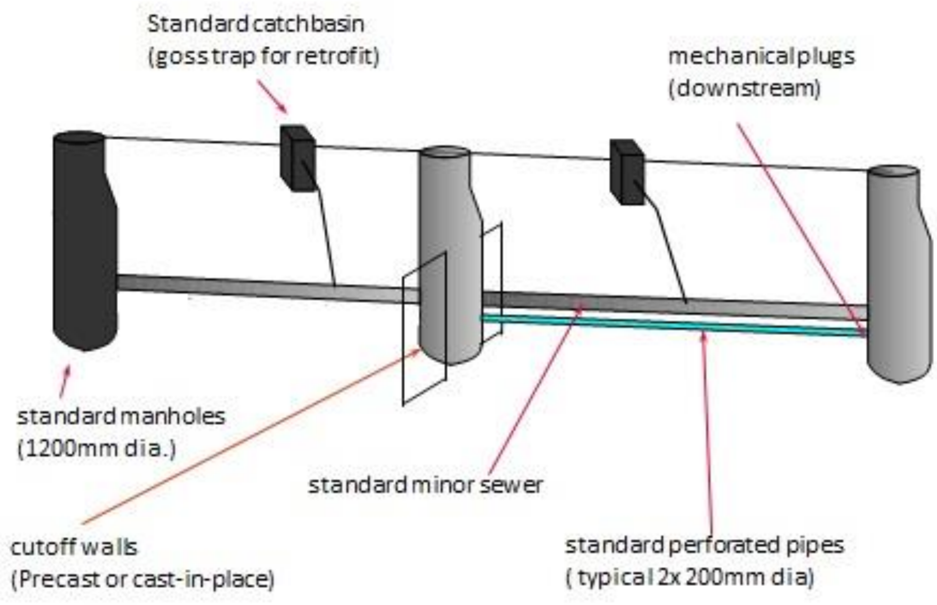

Figure 1 Layout of Etobicoke exfiltration system.

2 PLANNING AND DESIGN CRITERIA

2.1 Planning Criteria

A two-step evaluation procedure has been developed for the EES. The first step comprises the following most critical screening questions:

1. Is a water supply aquifer absent at the site of interest (reduced ground water contamination)?
2. Is the site of interest a low density residential area (less polluted runoff)?
3. Is the site of interest served by local roads (reduced spill potential by industrial trucks and structural consideration of perforated pipes)?
4. Is the ground water table below the invert of the exfiltration pipes?

All of the first step questions must be answered affirmatively without exception in order to continue to the second step. Regarding Question 4, the EES can still be considered suitable even the ground water table is less than 1 m (typical for infiltration/exfiltration devices) because runoff will be exfiltrated horizontally along the storm sewer trench in addition to vertically downward.

The second step comprises the following secondary questions:

5. Are the roads and/or sewers in poor condition (increased retrofit potential and saved cost)?
6. Is the tree root problem absent at the site of interest (trees with deep roots need relocation to prevent roots from damaging filter cloth and perforated pipes)?
7. Is the required maintenance equipment available at the municipality (reduced long-term maintenance cost)?

All of the second step questions should be answered affirmatively, either with or without implementation of engineering measures designed to remedy the associated environmental impacts. If there are additional environmental impacts associated with the engineering measures, then the EES is not suitable for a site of interest.

2.2 Design Criteria

The only two criteria are : (1) the sizing of EES to capture 90% of annual rainfall events (e.g. 15 mm rainfall event depth in Toronto) ; and (2) exfiltration of the captured volume in 2 days. These design criteria apply only to existing and new residential area having a ratio of no more than 2 ha/100 m of storm sewer.

2.3 Design approach

Design starts from the second most upstream sewer where the contributing area to the first most upstream sewer will be used to size the EES storage (volume of perforated pipes plus the void space of the sewer trench aggregates) equivalent to the runoff of a 15 mm rainfall event volume. Sizing of subsequent downstream EES can be continued until the second most downstream sewer. Figure 2 depicts the design approach from upstream to downstream.

3 CONSTRUCTION AND MAINTENANCE

3.1 Construction Procedure

The construction procedure of the EES is listed below:

1. Excavation of the trench was undertaken using standard construction techniques.
2. Filter cloth was placed around the trench and held on the sides of the trench by stakes.
3. Granulars of 13-mm size were placed from the bottom of the trench to the design invert of the perforated pipes.
4. Two 200 mm perforated pipes wrapped with filter cloth were placed on the granulars and mechanical plugs were placed on both upstream and downstream ends.
5. Granulars were placed over and around the perforated pipes until the elevation of the invert of the sewer was reached.
6. The storm sewer was laid above the granular layer.
7. Catchbasins were installed with leaders connected to both perforated pipes and sewers
8. Granulars were placed over and around the sewers.
9. The filter cloth was wrapped over the granulars with an overlapping width of 1 metre.
10. The trench was then backfilled with suitable soils.
11. The mechanical plugs at the upstream end of each section of the EES were removed after all construction.

A year after the construction, a sewer and perforated pipe inspection was conducted at an upstream EES section. It was found that only the downstream end of the exfiltration had some sediment deposition and the water marks were observed only at the downstream end of the EES. Thus, there was no overflow to the upper sewers at the upstream end of the EES. In 2014, another inspection was conducted by the Toronto and Regions Conservation Authority and the results indicated that the majority of exfiltration pipes were not filled with sediment. Thus, the EES appears to be working without maintenance required.

4 COST

The cost of the EES for the case study was determined by comparing with a control site with similar type of construction. As indicated in Table 1, the additional cost is approximately 4% of the road reconstruction.

5 PERFORMANCE

Field monitoring of performance was conducted one year and five years after the construction. Fourteen rainfall events ranging from 11 mm to 63 mm and 0.5 hr to 48 hrs were recorded at the site. Only three events (63 mm over 18 hrs; 26.8 mm over 2.5 hrs; and 15.3 over 0.75 hr) triggered the sewer overflows. The other rainfalls (e.g. 20.8 mm over 4 hrs) did not trigger sewer overflows. These results indicates the exfiltration over rainfall periods can provide additional volumetric control of runoff.

Table 1 Cost of Etobicoke exfiltration system.

Cost without EES		Cost to retrofit EES	
Part A – Drainage	$122,531	Part A – Drainage with EES	
Part B – Road	$533,991	Drainage	$122,531
		Additional cost	$ 24,918
Total amount	$656,522	Total Part A	$147,449
		Part B – Road	$533,991
		Total amount	$681,440
		Cost of EES (% total amount)	≈ 4%

6 CONCLUSIONS

The EES is a new approach to control storm runoff in new development or retrofit because it does not need surface space and works over four seasons (e.g. sewers are below frost lines and snowmelts can still enter the EES). Using the pore space of sewer trench and the perforated pipes to storage and exfiltrate surface runoff, it can provide sufficient storm runoff control up to 90 percentile of rainfall events and recharge to ground water. Construction of EES does not require special equipment or method. After 20 years of operation, the majority of the EES still provides runoff control. Cost of EES is relatively minor compared with the cost of road construction. EES was found to provide very good runoff control up to 90 percentile rainfall events.

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